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Centre canadien de la technologie des minéraux et de l'énergie

Energy Research Laboratories

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Saint Mary's University

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Department of Chemistry

PROJECT MANAGEMENT AND SCIENTIFIC SUPPORT

FOR THE

CANADIAN ADVANCED FLUIDS RESEARCH GROUP

Final Report 1990-92

submitted to the
Energy, Mines and Resources Canada
CANMET - ERL Division

by

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MICROMEDIA

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Summary

The following report discharges our commitments under our current research contract with Energy Mines and Resources Canada (EMR) which expired, after extension, on April 30, 1992, and presents a proposal for a further contract for the period April 1, 1992 - March 31, 1993.

An "Advanced Fluids Research Centre" was recently established at Saint Mary's University to help publicize our past achievements and to consolidate and facilitate our future project work on district heating and cooling technologies in general and "advanced fluids" in particular. Completed project activities and those continuing through the end of the current contract period include the following:

i) **fundamental studies of the relationship between the chemical structures of friction reducing agents (FRAs) and their drag reducing capabilities.** This work has led to the development of practical FRA formulations for low temperature applications, for which patent applications have been made. This low temperature additive development work is continuing.

ii) **studies of the effects of FRAs on the performance of commercial corrosion inhibitors and *vice versa*.** Results reported to date indicate that interactive effects on corrosion inhibition are in fact marginally beneficial, and that an observed separating tendency of FRA/corrosion inhibitor combinations did not affect drag reduction, at least in short duration laboratory tests conducted to date. Analytical studies are under way to identify the chemical nature of the precipitating components in these complex combined additive mixtures, after which longer duration performance tests will be initiated

iii) **studies of the relative durabilities of FRA formulations and the effects on durability of environmental factors (temperature, pH level, dissolved oxygen and metal ion content).** Initial work in this area has been reported, and current efforts are directed towards developing and validating an accelerated aging test using our "torture machine", in which a gear pump forces fluid through tubes of small diameter at high velocities. Test results will be compared with those obtained from an improved laboratory flow test system currently under construction and from a planned full-scale test in the cooling system of the Patrick Power Library of Saint Mary's University.The Saint Mary's University Advanced Fluids Centre is currently negotiating a collaborative study of FRA degradation with experienced specialists at the University of Dortmund, Dortmund, FRG, and has initiated discussions with engineeering faculty members of the Technical University of Nova Scotia concerning a joint study of long-term FRA durability in pilot-scale pipeline systems

iv) **studies of the corrosiveness of FRAs..** The Centre has completed and reported a study of FRA corrosiveness which it carried out in collaboration with the Nova Scotia Research Foundation Corporation, and the Centre has recently acquired a sophisticated potentiostat system designed for carrying out accelerated corrosion testing. This system should be fully operational within three to six months

v) **education and information dissemination on district heating and cooling in general, and on FRAs in particular.** Much of the research program of the Centre is being carried out by graduate and undergraduate students, and they and the Principal Investigator have made numerous presentations on these technologies, both verbally and in print, to student groups, professional meetings and the general public, and also in discharging our responsibilities to the Canadian Advanced Fluids Research Group and the International Energy Agency's District Heating and Cooling Experts Group on Advanced Fluids.

Short-term priority tasks include further work on the degradation resistance of FRAs and their interactions with commercial corrosion inhibitors. However, at this time, we are confident that we have developed viable FRA formulations suitable for use in cooling applications, and we are looking forward to opportunities to test them in full-scale systems in 1992-93.

Sommaire

Le présent rapport fait état de nos obligations dans le contrat de recherche avec Energie, mines et ressources Canada (EMR) qui expire le 31 mars 1992 et présente une proposition pour un prochain contrat pour la période du 1er avril 1992 au 31 mars 1993.

Un centre de recherche sur les fluides c'est récemment établi à Saint Mary's University pour aider à publiciser nos réalisations et à consolider et faciliter nos projets d'avenir concernant les technologies de climatisation et de chauffage ainsi que les fluides. Les projets complétés et ceux poursuivis jusqu'à l'échéancier du présent contrat comprennent les sujets suivants:

(i) l'étude fondamentale des relations entre les structures chimiques des additifs réducteurs de friction et leur efficacité. Ce travail a récemment permi de développer des formules chimiques utiles pour l'application en basse température.

(ii) l'étude de l'effet des ARF sur la performance des réducteurs de corrosion commerciaux et vice-versa. Jusqu'à présent les résultats obtenus indiquent que les effets interactifs sur les réducteurs de corrosion sont en fait avantageux et que la tendance de séparation de la combinaison ARF/réducteur de corrosion n'affecte pas la réduction de la turbulence, du moins pour les courts tests exécutés jusqu'à maintenant en laboratoire. Des études analytiques sont amorcées afin d'identifier la nature chimique des composantes qui précipitent dans cette combinaison complexe d'additifs, ensuite des tests de performance de longue durée sont projetés.

(iii) l'étude de la durabilité relative des formules d'ARF et de l'effet sur la durabilité des facteurs environnants (température, niveau d'acidité pH, oxygène dissout, quantité d'ions de métal) Les rapports ont été rédigés pour le travail initial dans ce domaine et présentement, la recherche est orientée dans le developement et l'évaluation des tests de dégradation des ARF qui font usage de la "machine à torture". Cette dernière comprend une pompe qui force les fluides à passer dans des tubes de petit diamètre à des velocités élevées. Les résultats seront comparés à ceux obtenus du système amélioré pour la mesure de courant présentement en construction. Le Centre négocie présentement une étude collaborative de la dégradation des ARF à l'aide du personnel spécialisé de l'Université de Dortmund, en plus d'avoir discuté avec les membres de la faculté de génie de la Technical University of Nova Scotia d'une étude de la durabilité à long terme des ARF dans un réseau de distribution à échelle réduite.

(iv) l'étude de la corrosivité des ARF.. Le Centre à complété et fait état de l'étude de la corrosivité des ARF en collaboration avec la Fondation corporative de recherche de la Nouvelle-Écosse. Le Centre est récemment devenu requéreur d'un système potentiostate sophistiqué qui permet de tester rapidement la corrosivité. Ce système devrait être complètement opérationel dans 3 à 6 mois.

(v) éducation et information sur les systèmes de climatisation et de chauffage urbains en général, et plus particulièrement sur les fluides. La plupart des programmes de recherche du Centre sont sous la responsabilité d'étudiants gradués ou sous-gradués. Ces derniers ainsi que les investigateurs principaux ont donné de nombreuses présentations concernant cette technologie, autant verbalement que par écrit, à des groupes d'étudiants, des rencontres de professionels et le public en général. Il ont aussi présenté nos responsabilités au Groupe canadien de recherche sur les fluides et au groupe d'experts en fluides avancés du domaine de climatisation et de chauffage urbain de l'Agence Internationale d'Énergie.

Les tâches à court terme comprennent une étude plus approfondie de la résistance à la dégradation des ARF et de leurs interactions avec les
additifs réducteurs de corrosion. Présentement, nous sommes confiants que nous avons dévelopé des ARF appropriés pour l'usage dans des systèmes de refroidissement et nous espérons pouvoir effectuer des essaies dans des réseaux à grande échelle.

To Whom It May Concern:

We are pleased to provide the following final report on our current contract with Energy, Mines and Resources Canada for "The Continuing Provision of Project Management and Scientific Support for the Canadian Advanced Fluids Research Group" (DSS Contract No: 23440-9-9302 / 01-SS).

This report consists of:

i) a background statement (Section 1.0);

ii) a report on the status of our project as of March 31, 1992 (Section 2.0); and

iii) a proposed "Statement of Work" (Section 3.0) and budget (Section 4.0) for a new contract for the period April 1, 1992 - March 31, 1993

1.0 BACKGROUND

On June 21, 1990, the Advanced Fluids Research Group of Saint Mary's University was awarded a research contract by Supply and Services Canada to provide project management and scientific support services for the Canadian Advanced Fluids Research Group activity of the CANMET-ERL Division of Energy, Mines and Resources Canada (Contract No. 23440-9-9302 / 01 -SS). The basis for this award was a contract proposal which I, as Principal Investigator, submitted to Supply and Services Canada (J.C. O'C. Young to P. J. Monelly, proposal of May 18, 1990 with cover letter dated May 21, 1990). This contract was scheduled to meet expenditures incurred in connection with our project over the period July 1990 through March 1992.

On June 14, 1991, the Scientific Authority for our project (then Michael Wiggin, EMR - CANMET) recommended that its scope be expanded in the period October 1, 1991 to March 31, 1992, and also that the project be extended through March 31, 1993 and proposed a revised "Statement of Work" for this eighteen month period (M. Wiggin to P. Pint, memorandum dated June 14, 1991).

On August 26, 1991, the Scientific Authority asked us to prepare a supplementary contract proposal to support additional work in the period October 1991 through March 1992, and indicated that the program for fiscal 1992-93 would be negotiated separately and later (M. Wiggin to J. C. O'C. Young, memorandum dated August 26, 1991).

On October 8, 1991, we received a formal "Request for Proposal - Contract Amendment" from Supply and Services Canada (N. Nishikawa to C. Dodds, letter dated October 8, 1991), in which we were asked to submit to a new Scientific Authority (Lynn Ciavaglia, EMR / CANMET - ERL) a revised technical program and cost breakdown for a program through March 31, 1992. Given the short period to contract expiry, we chose to submit a

technical plan for the period through March 31, 1993 with the requested cost breakdown for the program through March 31, 1992 only (J. C. O'C. Young to N. Nishikawa, memorandum dated November 27, 1991). The proposed "Statement of Work" for the period through March 31, 1993 is reproduced in APPENDIX A1 to serve as a frame of reference for this report and as the basis for a new contract proposal for fiscal 1992-93.

Our activities in the fiscal year 1990-91 were presented to the Scientific Authority in a series of written and verbal reports. In addition, papers on our work were given at various public and technical meetings and at scientific conferences. Arising from this work, we have also filed a patent application on "Hydraulic Drag Reducing Agents for Low Temperature Applications" on behalf of Energy, Mines and Resources Canada.

Reports of our work published and/or presented to the Scientific Authority in the fiscal year 1991-92 include:

1 - "Advanced Fluids for District Cooling Systems", a report to the International Energy Agency's District Heating and Cooling Experts Group on Advanced Fluids , April 9, 1991

2 - "Advanced Fluids for District Cooling Systems: A Review and Progress Report", (invited plenary paper) in Bohm, B. (ed.), *Proc. Internl. Symposium on Fluids for District Heating*, Copenhagen, Denmark, April 10, 1991 (ISBN 87-88038-23-8)

3 - "Investigations of Interactions Between Hydraulic Drag Reducing Agents and Corrosion Inhibitors" (with the Nova Scotia Research Foundation Corporation), April 20, 1991

4 - "Hydraulic Drag and Heat Transfer Properties of Dilute Aqueous Surfactant Solutions under Turbulent Flow Conditions", BSc (Hons.) Thesis, April 22, 1991

5 - "A Small-Scale Laboratory Assessment of the Behavior and Performance of the DOBON-G / Salicylate Drag Reducing Agent", report to the Prince Edward Island Energy Corporation, September 29, 1991

6 - "The Continuing Provision of Project Management and Scientific Support for the Canadian Advanced Fluids Research Group", October 12, 1991

7 - "Pipeline Friction Loss and Heat Loss Reduction", Energy, Mines and Resources Research Agreements Program 1990, Final Progress Report, November 1, 1991

8 - "Effects of Corrosion Inhibitors and Anti-Foaming Agents on the Performance of Hydraulic Drag Reducing Agents", February 19, 1992

Given the ongoing nature of this project and its anticipated continuance through March 31, 1993, a number of subprojects have been started which are currently in progress and will not be reported by the expiry of our current contract on March 31, 1992. Amongst these are:

9 - A one-year study of the use of a Langmuir surface film balance (purchased for the project by Saint Mary's University) to compare the effectiveness of alternative surfactant counterions for use in FRA formulations. (This study is virtually complete, and an initial presentation of its findings will be made in mid-May, 1992)

10 - A study of the measurement of the (non-Newtonian) viscocities of FRA concentrates and working solutions using a novel falling pin viscometer (purchased for the project by the International Energy Agency). (This study is also virtually complete)

11 - Further electrical conductometric studies of the cmc and mtc values of alternative FRA formulations. (A progress report on this work will be made during the summer of 1992)

12 - A study of possible commercial synthesis routes and sources for the FRA counterion component. (This subproject was started recently)

13 - Work in progress on determining the nature and significance of chemical interactions between FRAs and corrosion inhibitors and other additives to, and contaminants in, district heating and cooling distribution systems. (This work is a continuation of that described in "Effects of Corrosion Inhibitors and Anti-Foaming Agents on the Performance of Hydraulic Drag Reducing Agents", February 19, 1992 (listed as Item #8 above)).

We can also report significant progress on the establishment of the Saint Mary's University "Advanced Fluids Research Centre". Space renovations are now complete and several major equipment items have been moved into this new laboratory space, including a versatile accelerated corrosion monitoring system for studying effects of FRAs on the corrosiveness of circulating water flows in district heating and cooling systems. The refrigeration unit and other major components of a new flow test loop have been ordered and construction of this system should be complete by mid-summer. We anticipate having the laboratory in full operation by the time we host the meeting of the IEA's District Heating and Cooling Experts Group on Advanced Fluids which is scheduled to be held at Saint Mary's University on October 1-2, 1992. Subject to adequate funding, we hope to employ as many as 6-8 elite undergraduate students and recent graduates and provide them with valuable research training in the laboratory during the summer of 1992. Also, we are continuing to publicize the merits of district heating and cooling technologies through the media and other means.

2.0 STATUS REPORT ON OUR "STATEMENT OF WORK"

The following report is presented under the headings listed in the "Statement of Work for the Period October 1991 through March 1993" given in APPENDIX A1 (source: N. Nishikawa to C. Dodds, letter of October 8, 1991):

a) *definition of emerging compatibility problems with FRAs and corrosion inhibitors, pipe materials etc., and development of mitigating measures. This will include new additives for broader temperature spectrum application and new variations in inhibitor chemistry*

Two studies of FRA interactions with pipeline materials (iron and copper) and with corrosion inhibitors were reported in the contract periods (Items #3 and 8 in the above list of publications). While our latest FRA designs appear to be insensitive to the presence of typical commercial corrosion inhibitors, and *vice versa*, at least in short duration tests, much remains to be learned about these complex interactions, and work in this area is continuing as our "number one" priority. This topic is closely related to that of FRA degradation which is discussed under heading b) below.

Friction reducing additives consist of an amphiphilic cation component and negatively charged counterions which draw the positively charged surfactant molecules together into colloidal micelles above a minimum addition level of the FRA cation/anion pair, which is commonly referred to as its "critical micellar concentration" or cmc value. The Krafft Point of a micellar system is the temperature at which the solubility of its monomeric form reaches its cmc value. Micelle formation formation occurs above this temperature but, at lower temperatures, the monomeric form precipitates out before micellation can occur. A necessary (but not sufficient) condition for a micellar system to be useful as an FRA is that its Krafft Point be lower than the minimum desired operating temperature of the pipeline system in which it is to be used.

Our early efforts to develop FRAs for low temperature applications centered on exploring the effects of counterion structure on the cmc values of the n-decyl and higher members of the homologous series of n-alkyltrimethylammonium surfactants (see, for example, Murray, C. B., "Micelle-Forming Characteristics and Drag Reducing Capabilities of Selected Nitrogen-Containing Surfactants at Sub-Ambient Temperatures", BSc (Hons.) Thesis, Saint Mary's University, August 1989). A major aim of this work was to find counterion structures which would lower the Krafft Point below 0 degrees Celcius, as is required for FRAs for use in ice slurry-based district cooling systems. This and subsequent studies showed that the performance of the "standard" salicylate counterion could be substantially improved either by the addition of a second hydroxyl ion in the unoccupied position adjacent to the carboxyl head group or by the insertion of a methyl group in the meta or para position. With either of these counterions, surfactants as "long" as the dodecyl member were soluble enough to exhibit Krafft Points below 0 degrees Celcius and were thus able to form colloidal micelles (the precursor of drag reducing capability) at this temperature.

Using two of these modified carboxylate anions as reference counterions, namely 3-methyl salicylate and 2,6-dihydroxybenzoate, a corresponding attempt was made in the present study to optimize the design of the surfactant component (Item #4 above). It was found that insertion of a mid-length double bond in the alkyl "tail" and substitution of 2-hydroxyethyl groups for two of the methyl groups attached to the nitrogen atom produced FRAs with Krafft Points substantially below 0 degrees Celcius even for members as long as the 9-octadecenyl-bis(2-hydroxyethyl)-methylammonium cation. (This surfactant is manufactured commercially as the product "Ethoquad O/12" by the Akzo Chemicals Inc., a member of our Canadian Advanced Fluids Research Group).

While we may well be able to develop superior FRAs in the future, the product of the above optimization process does appear to be a viable FRA for low temperature applications, and it certainly meets the requirement that we develop "*additives for broader temperature spectrum application*", since we have shown it be effective down to 0 degrees Celcius and up to at least 50 degrees Celcius.

It should however be noted that ethoxylation substantially reduces the critical wall shear stress of the FRA and will likely increase its chemical reactivity. The significance, if any, of these effects remains to be determined.

Finally, within the past two weeks, we have succeeded in synthesizing but have yet to test a counterion which contains both of the apparently desirable modifications of salicylate, namely a second hydroxyl group adajacent to the carboxyl head group and a methyl group in the para position (4-methyl-2,6-dihydroxybenzoate).

Because there are applications for which environmental concerns may dictate that ammonia-based surfactants not be used, we have recently directed our attention to the possibility of developing drag reducing additive systems based on nitrogen-free surfactants. Some, as yet unreported, work has been done on effects of the structure of this type of surfactant on its critical micellar concentration. However, this is a long-term study which is unlikely to produce practically useful results in the near future.

b) development of analytical procedures for monitoring and detecting additives and additive concentrations and to evaluate the deterioration of additives in real systems

By this time we had expected to have test results on the *"deterioration of additives in real systems"*. However, for reasons beyond our control, our planned test program in the Charlottetown district heating system was aborted by the Prince Edward Island Energy Corporation.

We are continuing our studies of additive deterioration in our small-scale laboratory systems (Items #3 and 8).

As part of our preparations for the Charlottetown test, we did work up a laboratory procedure to monitor the presence of the surfactant component.

c) *cooperation with other Canadian partners (eg CANMET / NRC) in investigating the side effects of additive use on heat transfer deterioration etc and the development of mitigatory measures or design strategies*

Under this heading we have provided minor consulting services to Lynn Ciavaglia of CANMET, to Bryan Knodel, a contractee to CANMET, and to Raj Gupta of the Low Temperature Laboratory of NRC.

d) *coordination of contacts with CANMET and dissemination of information for or on behalf of CANMET in the following manner:*

1) *production of an advanced fluids newsletter that will be distributed to the Canadian Advanced Fluids Research Group (CAFRG) and others that can be used as source material for CANMET and for national and international journals for publication.*

   A draft design for CAFRG newsletter has been prepared and submitted to the Scientific Authority.

2) *support of the incorporation of new developments in advanced fluids / FRA research into academic training in Canada*

   The Principal Investigator has discussed district heating and cooling and advanced fluids with university student groups and while on speaking tours.

   The Principal Investigator's undergraduate research training program has provided opportunities for students to become aware of and involved in advanced fluids research, and has encouraged many of these students to continue on to graduate studies with the intention of pursuing careers in scientific research..

   The Principal Investigator is currently discussing with the Division of Chemical Engineering of the Technical University of Nova Scotia the possibility of a joint student training and research project on an advanced fluids (which would also provide us wuith local access to larger scale flow testing equipment).

3) *promotion of interaction of Canadian workers in the field of advanced fluids / FRAs with other experienced international workers.*

   The Principal Investigator is currently preparing a joint research proposal on FRA degradation with the Drs. Steiff and Weinspach of the University of Dortmund for submission to a meeting of the IEA DHC Experts Group on Advanced Fluids to be held in Dortmund, FRG, in March, 1992.

On behalf of the Canadian Advanced Fluids Research Group, the Principal Investigator presented an invited plenary paper on "Advanced Fluids for District Cooling Systems: A Review and Progress Report" to the Nordic Council of Energy Ministers International Symposium on Fluids for District Heating held in Copenhagen in March 1991.

His laboratory has entertained visitors from China, Japan and elsewhere during the past year.

Specifically within Atlantic Canada, undertake the following:

1) *participate in or host periodic regional seminars on FRA technologies.*

While we have yet to participate in or host a regional seminar on FRA technologies, the Principal Investigator has given numerous talks to local groups on the subject. Some recent examples include:

- a briefing for staff members of the NS Department of Natural Resources,

- a presentation to the Board of Governors of Saint Mary's University

- discussion of the Saint Mary's University FRA project in numerous speeches made on the subject of "Undergraduate Research" during a speaking tour at universities throughout the Atlantic Provinces conducted by the Principal Investigator on behalf of the Atlantic Provinces Interprovincial Committee on the Sciences

- discussion of the project in a talk on "Teaching Problem-Solving" at the Nova Scotia Association of Science Teachers 1991 Annual Conference

2) *act as an Atlantic region technology resource / contact on behalf of national district heating and cooling program or activities.*

In this capacity, the Principal Investigator acted as a consultant to the PEI Energy Corporation in regard to plans for a large-scale FRA test in the Charlottetown district heating system.

He collaborated with corrosion specialists at the Nova Scotia Research Foundation Corporation in a study of the corrosiveness of FRA formulations.

He took part in planning meetings on the use of low-grade, geothermally heated water from coal mines for a proposed district heating system in Charlottetown.

The Principal Investigator and his students gave talks on FRAs at several conferences in the Atlantic Region, in Environmental Displays and in a local shopping mall during the 1991 Science & Technology Week.

He discussed district heating and cooling and advanced fluids in a reply to an invitation from the Nova Scotia Minister of Natural Resources to members of the Energy Strategy Roundtable to comment on his Ministry's recently released publication "Energy Strategy 1991: A Framework for Discussion" (see APPENDIX A3). He also gave a briefing on the subject to senior staff members of the Department of Natural Resources.

e) *act as the Canadian representative to the IEA's Advanced Fluids Experts Group. Attend required meetings, meet with Canadian experts, package and disseminate information, negotiate further R&D to be done in Canada on behalf of the IEA Implementing Agreement on District Heating R&D.*

The Principal Investigator has attended and participated as the Canadian Country Representative in all meetings held by the IEA's District Heating and Cooling Experts Group on Advanced Fluids and by the Canadian Advanced Fluids Research Group during this and previous contract periods. He has prepared and circulated notes on these proceedings.

He participated in the successful negotiation of Canada's R and D contract under Annex III of the IEA's District Heating Implementing Agreement and is currently negotiating a joint Canadian-German project for the proposed Annex IV program.

The Principal Investigator will host a meeting of the IEA's DHC Experts Group on Advanced Fluids at Saint Mary's University in Halifax, N. S., on October 1-2, 1992.

f) *impact of FRAs on Heat Transfer -- In the development of FRAs, the reduction of turbulence also reduces heat transfer coefficients in heat exchangers, boilers, etc. To assure that the FRA development work reflects impacts on heat exchanger performance, it is required that this aspect be evaluated. The evaluation should show and quantify degradation in heat transfer and develop guidelines as to how this might be minimized or avoided.*

In this area, we have carried out and reported the results of a substantial experimental study of FRA effects on the heat transfer performance of a small shell-and-(single) tube heat exchanger (Item #4). The reduction in the inside film heat transfer coefficient was, in most tests, shown to be some what greater than the corresponding reduction in drag and approached 90% in some instances. However, we continue to believe, but have yet to substantiate, that this problem can be overcome or at least alleviated by running pipelines below but heat exchangers above critical wall shear.

We are currently constructing a larger flow test system which, amongst other things, we plan to use to study the effects of FRAs on shell-and-(multi)tube and plate heat exchangers.

g) *environmental and regulatory issues relating to the use of drag reducing agents.*

Since our current research contract was issued, our collaborators in the IEA Advanced Fluids Project from the University of Dortmund, FRG, received a research contract from the International Energy Agency to examine environmental issues relating to the use of drag reducing agents and to evaluate alternative procedures for their safe disposal.

In these circumstances , we have thusfar restricted our own activities in this area to an assessment of the mammalian toxicity of our additives and the submission of our findings to several provincial environmental agencies for their review, and to a successful search for a non-toxic, food-grade additive to make additive solutions extremely bitter.

We also plan to review and summarise the finding of the Dortmund study as they become available.

h) *development and experimental validation of criteria for scaling laboratory drag reduction results to predict additive performance results in full scale systems.*

Our experimental data (reported by Day, S.: "Hydraulic Drag and Heat Transfer Properties of Dilute Aqueous Surfactant Under Turbulent Flow Conditions", April 1991) indicate that constant critical wall shear stress is a reasonable "rule of thumb" for allowing for pipeline diameter effects on additive performance.

However, following the construction, currently in progress, of multi-diameter flow loops in our laboratory and in the Low Temperature Laboratory of the National Research Council, which will together span a diameter range from below 1 to above 10 cm, we expect to be able to develop a more sophisticated scaleup criterion.

3.0 PROJECT PROPOSAL for the Period April 1 1992 through March 31, 1993

Our project proposal for 1992-93 continues to be that which we outlined for this period in the extension proposal for our previous contract , which is reproduced in APPENDIX A1 of this report.

Our immediate priority tasks relate to the degradation resistance of FRAs, their interactions with commercial corrosion inhibitors and their potential environmental impacts. However, at this time, we are confident that we have developed viable FRA formulations suitable for use in cooling applications, and we are looking forward to opportunities to test them in full-scale systems in 1992-93.

4.0 BUDGET PROPOSAL for the Period April 1 1992 through March 31, 1993

Much of the equipment we require to carry the project through 1992-1993 was purchased under our previous 1990-92 grant. For this reason and because we already have a number

of subprojects underway , we present a much more labor-intensive budget for 1992-93.

This budget meets our needs to carry out our program commitments and, as a free side-benefit, it enables us to expand our educational role to our students - a role which we know has already encouraged several of our brightest students to commit themselves to potentially valuable careers in scientific research.

We wish to record that Saint Mary's University has made substantial contributions to our project. In addition to providing the normal institutional services, for which it has been compensated through overhead payments, the University has provided additional well-equipped dedicated laboratory space and has purchased a number of specialized items of equipment required for the project (including, most recently, a $25,000 surface film balance), while Honours Degree students have donated services to the project as part of their thesis work. Over the previous contract period, we estimate the value of these contributions to exceed $75,000 (J.C.O'C. Young to Michael Wiggin, memorandum dated June 21, 1991). In addition, the University has contributed a substantial part of the Principal Investigator's costs of travel in connection with the project because he has generally been able to combine these trips with a presentation on the subject matter of the contract to a scientific conference or meeting.

5.0 INTELLECTUAL PROPERTY RIGHTS

Patent action is currently in progress as a consequence of our current and previous contracts with Energy, Mines and Resources Canada, and further patent applications may reasonably anticipated in the future.

Under our present arrangement, the Crown is incurring all of the costs associated with this patent action, and any royalties accruing from issued patents will be shared equally between the Crown and Saint Mary's University. This arrangement is also acceptable to us in regard to the new contract here proposed.

Appendix A1

STATEMENT OF WORK

for the Period October 1991 through March 1993

a) definition of emerging compatibility problems with FRAs and corrosion inhibitors, pipe materials etc., and development of mitigating measures. This will include new additives for broader temperature spectrum application and new variations in inhibitor chemistry;

b) development of analytical procedures for monitoring and detecting additives and additive concentrations and to evaluate the deterioration of additives in real systems;

c) cooperation with other Canadian partners (eg CANMET / NRC) in investigating the side effects of additive use on heat transfer deterioration etc and the development of mitigatory measures or design strategies;

d) coordination of contacts with CANMET and dissemination of information for or on behalf of CANMET in the following manner:

   1) production of an advanced fluids newsletter that will be distributed to the Canadian Advanced Fluids Research Group (CAFRG) and others that can be used as source material for CANMET and for national and international journals for publication.

   2) support of the incorporation of new developments in advanced fluids / FRA research into academic training in Canada.

   3) promotion of interaction of Canadian workers in the field of advanced fluids / FRAs with other experienced international workers.

   Specifically within Atlantic Canada, undertake the following:

   1) participate in or host periodic regional seminars on FRA technologies.

   2) act as an Atlantic region technology resource / contact on behalf of national district heating and cooling program or activities.

e) act as the Canadian representative to the IEA on the Advanced Fluids Experts Group. Attend required meetings, meet with Canadian experts, package and disseminate information, negotiate further R&D to be done in Canada on behalf of the IEA Implementing Agreement on District Heating

R&D. (It is estimated that there will be one meeting in Europe for the IEA and about five meetings with the Canadian Experts Group - typically in Ottawa or Toronto. The contract would include semi-annual progress reports with a summary at the completion of pertinent developments.

f) impact of FRAs on Heat Transfer -- In the development of FRAs, the reduction of turbulence also reduces heat transfer coefficients in heat exchangers, boilers, etc. To assure that the FRA development work reflects impacts on heat exchanger performance, it is required that this aspect be evaluated. The evaluation should show and quantify degradation in heat transfer and develop guidelines as to how this might be minimized or avoided.

g) explore environmental and regulatory issues relating to the use of drag reducing agents.

h) development and experimental validation of criteria for scaling laboratory drag reduction results to predict additive performance results in full scale systems.

Appendix A2

PROPOSED PROJECT BUDGET

for the Period April 1,1992 through March 31, 1993

A. LABOUR		
1) Principal investigator (50 days at $400 / day)	$20,000	
2) Senior graduate assistants (56 weeks at $550 / week)	30,800	
3) Junior graduate assistants (16 weeks at $450/week)	7,200	
4) Senior u/graduate assistants (16 weeks at $400/week)	6,400	
5) Junior u/graduate assistants (16 wks at $350/week)	5,600	
5) Part-time student assistants (3 students at $667 each)	2,000	72,000
B. MATERIALS AND SUPPLIES		
Chemicals and consumables		5,000
Literature searching, publication acquisitions		3,000
C. EQUIPMENT		
Corrosion sample cutting and polishing		8,000
Additional instrumentation for flow test system		7,000
D. TRAVEL		
Travel, Ottawa consultations, IEA and CAFRG meetings		10,000
E. UNIVERSITY OVERHEAD		
30% of A1; 65% of A2 through A5 ; 2% of D		40,000
TOTAL		$145,000

APPENDIX A3

December 6, 1991

Your Ref.: 05-91-0044-04.2 (Vol. A)

Honourable C. W. "Chuck" MacNeil,
Minister, Department of Natural Resources,
Government of Nova Scotia,
PO Box 689, Halifax , Nova Scotia
B3J 2T9

Dear Dr. MacNeil:

After the frustration of heading up the Solar Energy Task Force and acting as a member of the Renewable Energy Task Force for the 1980 Nova Scotia Energy Plan, it was a distinct pleasure for me to read and be asked to comment on your Department's conservation oriented "Nova Scotia Energy Strategy 1991".

These are less optimistic times and the 1980 edition was quite different from the 1991 version, even though the numbers seem much the same. The 1980 "Plan" was, as I recall it, essentially a supply-side study of how to meet anticipated growth of energy demand; an anticipation based largely on the predictions of an EMR computer model that extrapolated past trends into the future - - which is not the way the future usually happens. The future tends not to be an extension of the past and it certainly wasn't in the 80s. While the model called for steadily increasing growth of demand over this period, primary energy consumption actually fell by (100 x (1 - 248.5 / 276.9 =) 10% between 1979 and 1989, according to the data given in Table A-2 on page 26 of the "Strategy".

Somewhat like the 1980 "Plan", the 1991 "Strategy" starts out from what I believe to be a

questionable premise, namely that, without substantial government intervention, we will experience fairly vigorous growth (2.3% per annum) in energy demand throughout the 90s. However, while the 1990 "Plan" sought to accommodate anticipated growth, the focus of the 1991 "Strategy" is on " . . . the specific steps the province will take to ensure that our energy situation in the year 2000 is different (i.e. lower) than that in the forecast" (page 5). Its emphasis on energy efficiency and energy conservation to curb demand is most welcome.

Your target of reducing the annual rate of growth of energy demand from 2.3 to 1.0% is impressive only if the first figure is not inflated. You indicate that the 2.3% growth forecast is based on an (unreferenced) end-use energy demand prediction which " . . . takes into account estimates of energy efficiency improvements; however, the forecast assumes there is only limited government intervention in the form of incentives or regulation" (page 30). With no government intervention at all, I find it hard to believe that primary energy demand would rise by (100 x (318.6 / 248.5 -1) =) 28% through the year 2,000, or that the component to meet electrical demand would increase by (100 x (139.9 / 93.5 - 1) =) 50% over the same period. Unless we currently have a lot of unused capacity at peak demand, this seems to suggest that we might have to increase our total provincial generating capacity by 50% over the next decade (data from Table 3 on page 5). Perhaps zero growth rate or a modest contraction might be achievable, and I suspect that we may be making a start in this direction in 1991 and 1992 because of general economic conditions.

Rather than projecting the past into the future to predict ever increasing electrical demand - - a projection which, like that of our university's student enrolment, will be true until it isn't - - we might better look at the experience of others who have already gone a little farther down the road than we have. As Amory Lovins has pointed out in great detail on many occasions, as many western US electrical utilitiies have long known, and as Ontario Hydro has recently discovered, it may be more profitable (as well as more societally responsible) for these utilities to bribe their customers to consume less of the product they sell. I am, of course, referring here to the price rebates paid by electrical utilities to those customers who purchase energy efficient appliances and light bulbs, and who improve the

insulation of their electrically heated homes. On the "stick" side, they seem to be resorting to, or at least looking into, pricing schedules under which the unit cost of electricity rises rather than falls with consumption level.

Turning from these generalities, I would like to make a few comments on specific components of the "Strategy", beginning with the "Strategy for Energy Efficiency and Conservation" in which you state that "The province will promote demonstration and information transfer activities that encourage cost-effective technologies suitable to Nova Scotia" (page 11).

One technology which currently merits this attention is the use of waste heat from electric power generation and other sources in large-scale space heating and cooling. This technology is particular appropriate to Nova Scotia because of our heavy dependence on thermally generated electric power and because, after PEI, we are perhaps the most urban province of Canada.

In 1986, EMR/CANMET/ERL brought together a group of federal government agencies and laboratories, universities and private industrial companies to develop and promote the use of district heating and (particularly) district cooling as part of a larger R & D inititiative in this field by the OECD's International Energy Agency. The main thrust of this technology is the use of waste heat to heat or chill water on a large scale in a central facility and then to distribute hot or cold water to points of demand through a pipeline network.

My research team at Saint Mary's University has been a member of this group since its inception, and our principal responsibility has been the development of chemical additives which inhibit turbulent eddy formation in water flows and hence substantially reduce the operating costs of pumping large quantities of water through the distribution network. (I gave a talk on this work to Carey Ryan and some of his staff members about a year ago, and we recently conducted a joint study with the Nova Scotia Research Foundation Corporation on corrosion-related aspects of this technology).

District heating and cooling is a technology to which EMR attaches considerable importance because of its large energy conservation potential and the new business opportunities it offers. As an example of these benefits, we are about to become involved in a district cooling system development in Lansing, Michigan, to which the attached recent press release by Federal Minister Jake Epp refers (ATTACHMENT 1).

We have a long way to go to catch up, given that, for example, approximately half of all the homes and businesses in Denmark are already heated cogeneratively through district heating systems of the type which is currently being demonstrated in Prince Edward Island. Built in 1985 and based on near state-of-the-art Swedish technology, this system now provides space heat to much of downtown Charlottetown as you are doubtless aware (see ATTACHMENT 2). Nearer to home, the Nova Scotia Power Corporation has recently held discussions with EMR officials concerning the possibility of using waste heat from the Tufts Cove Power Station for district heating and, even more recently, I had the opportunity to join with EMR officials, engineering consultants and members of the staff of the Town of Springhill in initiating a technical and economic evaluation of the use of geothermally heated water from the abandoned coal mines to serve a district heating and cooling system. This resource is already being used in a small way to provide space cooling in the plant of Ropak Can Am Limited in the Springhill Industrial Park.

EMR has stated its intention to establish a "Centre of Excellence" (an overworked term) for Research on Advanced Fluids for District Heating and Cooling at Saint Mary's University. We are very excited about this prospect because it will enable us to expand our current program of collaborative R and D activities and arrange exchanges with our partners in Canada, the United States, West Germany, Denmark and elsewhere. As part of this initiative, we intend to establish a comprehensive library of information relating to all aspects of district heating and cooling and to act as a clearing house for such information. In addition to support from EMR, you may be interested to know that we have submitted a proposal relating to this information gathering, analysis and dissemination activity to the Dalhousie-TUNS axis which is currently trying to put together a response to the call for the establishment of "A Centre for Excellence on Sustainable Economic Development" (another "centre of excellence"!!!), contained in the Canada-Nova Scotia Agreement on Sustainable Economic Development of March 18, 1991 (p. 26, section 2).

Amongst its efforts to ". . . promote demonstration and information transfer activities that encourage cost-effective technologies suitable to Nova Scotia", I hope that your Department will include district heating and cooling, and you may be assured that we would be pleased to assist in any way we can .

On page 11 of "Strategy", you state that the province " . . . will selectively use standards and regulations to improve energy efficiency"; and on page 16, you state that the province " . . will continue to identify, analyse, and work to overcome barriers to proven and promising alternative energy technologies". These are possibly the most appropriate and the most important actions that governments can take to promote energy efficiency, energy conservation and the use of alternative energy sources. On page 20, you state that regulatory authorities should be " . . . clearly accountable for their actions and decisions. Regulators must also monitor the impact of the regulations that they administer and provide feedback to the government in the form of recommendations regarding the appropriateness of the regulations".

I know from personal experience and the experiences of others the stultifying effects of regulations in the hands of risk-averse authorities who have absolutely no incentive to allow anything to occur which is not done in exactly the same way that it was done last time. Some, I am sure, would like to insist that a flagman must walk in front of every automobile. Although, not a Nova Scotian example, the installation of the Charlottetown district heating system is surely a classic case. To construct a viable, efficient system based on well-established European experience and practice, it seems that the operator was forced to fight or at least negotiate with regulators at every turn (ATTACHMENT 2). Nearer to home, fights between reactionary building inspectors and the designers and builders of passive solar and energy efficient homes were commonplace, although this battle now seems to be more or less won. And I could cite other examples.

Finally, to bring this long letter to a close, I would like to say something about alternative energy. Putting on another hat, as a current Board Member and the Founding Chairperson of the Solar Energy Society of Nova Scotia, I would like to express strong support for all five elements of your "Strategy for Alternative Energy" (page16). I would also like to express our gratitude for the past and continuing financial and other support that your

Department has given to the efforts of members of our Society to promote energy efficiency, energy conservation and the appropriate use of alternative energy sources.

A significant milestone for the Solar Energy Society was the financing and publication by your Department in 1981 of our report of "One Hundred and One Solar Energy Projects" (ISBN 0-8871-023-2). Since that time, alternative energies have made a small but I think significant further penetration into the energy marketplace, and have done so for the most part with little or no subsidization. We are pleased that members of our Society have taken a leadership role in bringing this about, some have achieved national and international recognition of their efforts, and a number have received your Department's Annual Energy Award . Our current Chairperson and sometime Harrowsmith centre-fold person, Don Roscoe, is I believe at this moment in Florida working on on a passive solar building commission. He has won competitions and achieved wide recognition for his innovative building designs, he has constructed many passive solar homes in Nova Scotia, he has given innumerable seminars on the design and construction of energy efficient housing, and he is the principal author of our very successful solar greenhouse course (with financial support form your Department). Each time I go out onto the roof of our Science Building and look across the rooftops of Halifax I think I see a greater number of Peter Allen's active solar collectors doing a cost effective job of pre-heating water to help service year-round hot water demands. Kerwin Davison's pioneering efforts at improving the efficiency of wood burning are another success story. Peter Havard's achievements in developing low cost solar collectors for agricultural purposes also come to mind.

Perhaps we should do more to publicise our successes.

Yours sincerely,

(Dr.) John C. O'C. Young
Department of Chemistry

Attachment 1

Extracts from PRESS RELEASE

October??, 1991

CANMET TO PROVIDE ANALYSIS OF LANSING, MICHIGAN, UTILITY'S DISTRICT HEATING AND COOLING PROJECT

OTTAWA - Jake Epp, the Minister of Energy, Mines and Resources Canada (EMR) announced that EMR will contribute to the evaluation of opportunities to increase the efficiency and cost-effectiveness of the Lansing, Michigan, Board of Water and Light's proposed district cooling system.

EMR's research and development arm, the Canada Centre for Mineral and Energy Technology (CANMET) will carry out the evaluation in collaboration with the utility and its consultants. . . .

For several years, CANMET has maintained partnerships and assisted Canadian companies with research and development of cooling systems that use smaller pipe sizes and new cooling liquids. . . .

The important advantages of these new technologies is the ability to generate chilled water near the freezing point or ice slurries. Both of these technologies can provide much more cooling with less water than is required for conventional chilled water systems. Low temperature friction reducing additives have also been developed that can reduce friction, and thus pumping energy requirements, by over 80 percent. The use of central cooling systems is seen as increasingly important as they facillitate the application of new chiller technologies that do not use chlorofluorocarbons (CFCs), compounds that have had a devastating effect on the ozone layer in the Earth's upper atmosphere. . . .

Extracts from BACKGROUNDER

DISTRICT COOLING TECHNOLOGY -
THE LANSING, MICHIGAN PROPOSAL

The project to be conducted at the Lansing Board Water and Light is seen as an important step in establishing the credibility of new technologies developed in Canada.

The U.S. Department of Energy (DOE) recently announced that eight U. S. projects - including the one in Lansing, Michigan - will be funded by DOE grants awarded as a result of a competition conducted last Fall. CANMET was specifically noted as a key player in the announcement of the award to the Lansing utility.

CANMET's project manager will serve as a broker between the utility and the Canadian companies who have developed new technology that may improve the efficiency of the Lansing district cooling system. The project manager will work with local engineering

consultants and contractors to examine the cost-effectiveness of a chilled water system. This will be compared with the lower energy costs and greater efficiency of the ice-slurry technologies that may be proposed as an alternative to the chilled water approach for the Lansing system. .

For several years, CANMET has managed a team of industry and academic researchers to develop more cost-effective district cooling technologies. The partners have included the National Research Council; Saint Mary's University in Nova Scotia; SUNWELL Engineering Company Limited of Toronto; Sorenco Ltee of Quebec; the Centre de recherche industrielle de Quebec (CRIQ); Dearborn Chemical Company of Toronto and CIMCO-LOCK Refrigeration also of Toronto.

CANMET has played a key role in managing this cooperative national effort to develop new district cooling technologies and in providing technical advice. CANMET has also provided financial support in the form of cost-shared contracts for the research and development program, and provided systems analysis to determine the requirements for technology development.

At a test loop in the National Research Council's Low Temperature Laboratory, scientists have been conducting experimental work on ice slurries. . . . The experiments have shown that mixtures containing between 20 and 30 per cent ice can be pumped in pipelines that are 70 per cent smaller than regular pipes. For example, in industrial systems, pipe sizes that are normally one metre in diameter would only be 20 or 30 centimetres in diameter if the system used ice slurry as a coolant.

In Nova Scotia, at Saint Mary's University, researchers have developed new friction reducing additives (FRAs) that make it approximately 80 per cent easier for chilled water to flow through pipelines. This has the effect of reducing the energy required to pump water though the system - and therefore cut costs - or allow the use of pipes that are 30 per cent smaller. These FRAs are currently being patented.

With the support of the Centre de recherche industrielle de Quebec (CRIQ), Sorenco Ltee has developed a new ice generator that supercools water . . .

The Dearborn Chemical Company's role has been to support the team in . . . the testing of FRAs for their compatibility with corrosion inhibitors and existing system materials.

SUNWELL Engineering Company Limited has provided an ice slurry maker for the NRC test loop as well as technical advice to solve problems with ice slurry systems. SUNWELL recently supplied a 1200 tonne capacity system for the Crystal Tower, the largest office building in Osaka, Japan.

Currently, CANMET and NRC are preparing design manuals on these technologies.

Attachment 2

The Implications of ANSI and ASME Codes on the Use of European District Heating Material in North America

R.J.Brandon - Prince Edward Island Energy Corporation
Miller West - Prince Edward Island Department of Labour

Abstract

In 1985 the P.E.I. Energy Corporation, located in Charlottetown, Prince Edward Island, Canada, began the construction of two block central district heating systems using wood fired boilers to supply the majority of the thermal load. From the outset it was decided to use European, in particular, Scandinavian materials and design philosophy wherever possible. The reason was to both reduce the installed cost and technical risk of the projects.

Because of the pressure and temperature requirements of the hot water distribution system, all components had to be approved by the Department of Labour under the Boiler and Pressure Vessel Act and its Regulations. These regulations stipulate that pressure retaining components must meet the minimum requirements of the ANSI/ASME Codes. The two systems, one of 5.3 MW peak and one of 13 MW peak are now in operation and use standard European heat exchangers, heat meters, ball valves, and pre-insulated piping.

Through extensive co-operation between the suppliers, and the Boiler Inspection Branch it has proved possible to register all the components of the installed system. The Paper will outline the relevant Code sections and indicate how suppliers of Standard district heating components can meet North American Standards and thus reduce the installed cost of new hot water systems.

1. BACKGROUND

Prince Edward Island is located in the Gulf of St. Lawrence, off the coast of New Brunswick and Nova Scotia. It is connected to the mainland by an underwater electrical power cable but the principal form of heating fuel that is used on the Island is light fuel oil which is imported from Venezuela via the refineries in Halifax. Over 50% of the area of the Island is forested and forestry surveys have indicated that close to 200,000 green tonnes of forest residue would be available annually for use as fuel. Starting in the late 70's a number of studies were carried out for various agencies in P.E.I. looking at the feasibility of using district heating technology to utilize the wood fuel resource and displace imported oil. It should be noted that the Island has relatively little industrial base and heating fuel is used primarily in the two urban centres of Charlottetown, population 15,700 and Summerside, population 8,000.

Rob Brandon, P.Eng. is the General Manager of the Prince Edward Island Energy Corporation.
Miller West is the Chief Boiler Inspector of Prince Edward Island.

Currently there are two district heating systems in operation in Charlottetown both using wood fuel. These projects are designed as heat islands that will be incorporated in a larger cogeneration system that is currently under active planning. One heat island, based on a wood boiler of 2 MW capacity at the Prince Edward Home, serves a network heating thirteen buildings having a peak load of 5.3 MW. The second, more recent project, is based on a 3.5 MW wood boiler at the University of Prince Edward Island and heats a total of forty buildings, including the University campus.

The intention of this Paper is to document how over the last four years, the type of materials and components used in the district heating system, has been influenced by the Codes and Standards in operation in Prince Edward Island and illustrate how concerns of the Regulatory Authorities were addressed to enable standard European, primarily Scandanavian, equipment to be used.

For two reasons, it was always considered desirable to use standard district heating components and materials. The first was a reluctance on the part of the Energy Corporation to 're-invent the wheel' when techniques and systems with an operating track record are available in Countries that have a long history of experience with hot water district heating. The second point is that especially since the decline of oil prices it has become paramount to install hot water district heating systems at the lowest possible cost. It has been our experience that even including shipping and part fabrication cost that European materials, because they are manufactured in large quantities for district heating application, offer the lowest cost solution to installing hot water district heating systems.

The Paper is organized on a chronological basis showing how the choice of materials has changed depending on construction and operating experience.

2. PRINCE EDWARD HOME TO PROVINCIAL ADMINISTRATION BUILDINGS INTERCONNECT

This project was the first hot water district heating line installed in Charlottetown and was constructed during the summer of 1985. A Schematic of the System is shown in Figure 1. The line was installed cold with expansion loops in the design. The pipe size was Dia 125mm (5"). In reviewing the available materials some consideration was given to using European pipe suppliers. However, there was a great deal of uncertainty on the part of the Corporation as to whether the standard district heating pipe which has a thinner wall, approximately Schedule 20, and a different steel composition would satisfy the requirements of provincial legislation. The relevant Act and Regulations provides for the approval of pressure retaining components associated with medium temperature hot water systems. Consequently, it was decided to specify fabrication in accordance with the ANSI/ASME B31.1 requirements using Schedule 40 materials. The pipe supplier selected was Weotherm, which is a division of Wik

& Hoglund of Finland. The pipe was manufactured in Ontario and apart from problems with the leak detection system, which is not the subject of this Paper, there were no installation problems with the Schedule 40 piping system. The installed cost of the pipe was CS630 per meter for a pipe run length of 250 meters.

The project required two heat meters to be located. One at the boiler plant end, and the other in the main Provincial Administration Building. Again, because of uncertainty as to whether European components would be approved, turbine insertion meters from a U.S. supplier were installed. The main control valve at the Building end was chosen by the contractor to be a Tour & Anderson valve supplied by a local control company. This valve, was of cast ductile iron construction and upon inspection by the Regulatory Authority, was found not in conformance with ANSI Standards with respect to material dimensions and marking requirements. This lack of conformance to referenced standards prevented the Regulatory Authority from issuing a Canadian Registration Number. After some discussion, an exemption was made for this one valve, but this experience alerted the Corporation to the potential problems of using standard European components in a Canadian regulatory environment.

2.1 Codes and Standards Applicable in Prince Edward Island

The fact that European fittings conform to other European standards, such as the DIN Standard, is not referenced in the Act and consequently is not directly relevant. As will be shown in the balance of the Paper, it has proved possible by the co-operative effort of suppliers, the proponent, in this case the P.E.I. Energy Corporation, and the Regulatory Authorities to meet the requirements of existing legislation and provide a mechanism for the approval of non-standard or specialized components.

3. CHARLOTTETOWN PILOT PROJECT

Following a study by AF Energikonsult, of Stockholm Sweden, into the technical and economic feasibility of a large scale district heating system for the City of Charlottetown, the P.E.I. Energy Corporation proceeded with a pilot project formed by connecting an additional 13 buildings to the boiler plant at the Prince Edward Home described previously in Section 2. The full system is shown in Figure 2. It was thought that this would yield good experience, both in the construction and operation of a small block central heating system. AF Energikonsult was commissioned to design the system. One of the directives given by the P.E.I. Energy Corporation to the Consultant was to maximize the use of proven materials and design concepts wherever possible. Code related difficulties are addressed by major component areas.

3.1 Heat Meters

A Canadian consultant, IEA Consulting Group, carried out a review of American and European heat meters and compared them using performance

criteria set out by the recently formed International Energy Agency sub-committee on heat meters. Eight manufacturers were identified as supplying heat metering equipment to the N.American marketplace. However, none of the European heat meters could satisfy the regulatory requirements for the issuing of a Canadian Registration Number. As the time frame did not allow for extensive delays in the approval of non-standard components, it was decided to go with a U.S. Manufacturer whose standard design and materials augered well for speedy approval by the Regulatory Authority. In operation, these meters proved problematic as the turbine design failed rapidly and the electronics proved unreliable.

3.2 District Heating Pipe

It was recognized from an evaluation of the Prince Edward Home to Provincial Administration Building project (2.0) that it was necessary to reduce installed cost of buried district heating line in order to make any large scale project feasible. Much of the cost of the initial project was due to the use of Schedule 40 pipe whereas the DIN Standard pipe common in Europe, or thinwall pipe, offered the potential of significant cost reduction.

A detailed review of the available DIN pipe material was carried out, and an effort made to reconcile this with the ASME steel requirements. It did not appear at the time to be possible to use European steel pipe. As a compromise, Ecopipe, a Finnish Company with a production plant based in Jolliette, Illinois, offered to supply 4-inch and 3-inch pipe that used API 5L Grade B electrical resistance welded pipe, that had a thickness intermediate between the Schedule 40 and the DIN pipe. It was not possible to use API 5L for the small diameter pipe such as ½, 1¼ and 1 inch and in these cases, A106 Grade B seamless Schedule 40 pipe was used. Ecopipe did offer for the smaller sizes dual stamped A53/A120 pipe but this was not deemed to be acceptable by the Regulatory Authorities. Inside the buildings, it was decided to go with Schedule 40 pipe using socket welding. Butt welding was specified for all buried pipelines.

Ecopipe was carried by the low bid contractor and in early spring of 1986, significant discussions occurred between the Contractor, the Corporation, the Regulatory Authority and Ecopipe to ensure that the Ecopipe piping system would meet all the requirements of ANSI B31.1. One particular area of concern was the welded tees and elbows that had to be fabricated in Ecopipe's shop and then pre-insulated and jacketed in their factory. The Regulatory Authority required 100% radiography in addition to the mill and hydro tests of the steel used both for the tees and elbows and for the straight pipe. Mill test reports sent initially by Ecopipe indicated that hydrostatic and flattening tests had not been carried out at the Mill and this caused additional delay while these omissions were cleared up. Some fittings included bent pipe and again the radius of bend and how it was carried out was of concern to the Regulatory Authority.

Eventually concerns reached such a point that the P.E.I. Energy Corporation sent the Contractor and Boiler Inspector to visit Ecopipe's facilities to ensure that problems during construction would not occur because of rejection of components of the piping system. This on-site visit proved to be extremely valuable in this instance and as can be seen was used later to great effect.

Once the material was supplied by Ecopipe, no further problems relative to certifying the system were encountered. Hydrostatic tests of the line were carried out prior to muffing the welded joints. Hydrostatic tests were imposed at 1½ times the working pressure and were held for a minimum of six hours and more usually overnight. The installed cost of the pipe system was C$428/meter for a total of 712 meters of trench length.

3.3 Heat Exchangers

Because of some poor experience with gasketed plate-type heat exchangers, the Corporation wished to use standard European spun-tube heat exchangers such as supplied by companies like ELGE and CTC. ELGE heat exchangers were specified as the standard for the 13 buildings that ranged in peak demand from 20 KW to 910 KW. A co-operative venture was finally established between ELGE and a local Shipyard whereby ELGE would supply the copper heat exchanger internal assemblies and would roll the steel components for the shell. The welding was done at the shipyard to avoid the problems of ELGE having to have them welded in an ASME facility in Sweden. The steel of ASME Standard was available in Europe, and the transfer of the heat numbers to the steel pieces was supervised by an Inspector brought in by ELGE. This Inspector held a National Board Commission acceptable to the Regulatory Authority. ELGE was also requested to submit detailed designs of their heat exchangers which were then registered by the Regulatory Authority as an approved pressure vessel design. Mill certificates had to be supplied by ELGE showing that all steel used was supplied to the appropriate grade. Again, due to co-operation from the Regulatory Authority and the inspection at each stage, it was possible to have European design fabricated to ASME and ANSI Standards at a reasonable cost.

3.4 Control Valves

The Engineer selected Tour & Anderson controls as a standard and originally the contractor had carried a complete Tour & Anderson control and control valve package. However, based on the Regulatory Authority's evaluation of the earlier T&A control valve located in the Provincial Administration Building, it was determined that the T&A control valves did not meet ASME and ANSI standards and would not be approved. The supplier of the controls then specified Barber Colman valves at a higher cost and there was some concern that the equal percentage area characteristic of these valves would not be as suitable for the application as the power linear characteristic of the originally specified Tour & Anderson valves. Experience showed that the initial concerns were realized especially on domestic hot

water applications where unacceptable flow noise was experienced at several sites at valve shutoff following a domestic hot water demand. One year after startup a special exemption was obtained to allow for bronze bodied Tour & Anderson valves to be used on the domestic hot water supply.

4. U.P.E.I. DISTRICT HEATING SYSTEM

In 1986 the Corporation initiated the design for a 13 MW district heating system based on the wood boiler complex at the University of Prince Edward Island. The scope of the completed system is shown in Figure 3. Phase 1 required a 1 km run across undeveloped land to a large shopping mall. In order to reduce installation costs, a preheated design concept was chosen by the Consulting Engineers, AF Energikonsult. In essence this concept requires laying the line in a trench without expansion elbows or loops. The cost reduction is due to the elimination of redundant welded joints and the cost of elbows and fittings. The line is laid in the trench and water circulated through both lines at 70°C. Expansion of the line is allowed to occur over a three-day period and then the pipe is backfilled along its entirety. The concept is that the pipe then is subject to mild compressive stresses in the supply line and tensile stresses in the return line during its normal operating life. The Regulatory Authorities expressed concern as to whether or not the line would exceed the yield stress in the event of unforeseen outages during the winter heating period. Calculations showed that with a ground temperature of -10°C, a period of 10 hours would have to elapse between the time that the line was fully drained and the time that steel would reach yield. It was concluded by the Regulatory Authorities that emergency repairs could be undertaken without subjecting the line to unnecessarily high stresses.

4.1 District Heating Pipe

A request for proposals for the supply of 6km of district heating pipe was entertained with six suppliers bidding. The Swedish District Heating Association Standard Specifications were used as the basis for the tender call. In addition it was stipulated that the pipe material must meet the requirements of the ANSI B31 Code. It appeared for the Phase 1 project that the simplest option was for European suppliers to bid API 5L pipe since this was available in Europe. Two European suppliers, I.C. Moller of Denmark and Power Pipe of Sweden were the two low bids. Interviews were held with representatives of both pipe supply companies. I.C.Moller was somewhat higher than Power Pipe but the total system approach and the greater experience of the I.C.Moller proposal resulted in their acquiring the order. In the Phase 1 design there were some fabricated fittings that had to be insulated in Denmark. Mr. Al Tanton, a quality control representative working for the Regulatory Authorities but paid for by the P.E.I. Energy Corporation, was sent to Fredericia, Denmark to inspect the welding procedures and the fabrication of these fittings. In addition, Mr. Tanton reviewed all mill test certificates for the pipe supply. No problems were

encountered in the supply of the API 5L pipe for Phase 1. Following successful completion of the Phase 1 piping contract, an application was made to the Regulatory Authorities by the P.E.I. Energy Corporation to approve the use of DIN Standard pipe. This would result in significant cost savings because the standard piping product of I.C.Moller could be used. The Swedish District Heating Association specifications specifies that steel carrier pipe should be steel meeting DIN 17100. An application was made by the P.E.I. Energy Corporation to the Advisory Committee of the Department of Labour to have this steel approved as a special exemption to the Boiler Pressure Vessels Act. After some discussion, this request was rejected for two reasons. One is that the steel has a unacceptable manganese content compared to API 5L, and secondly that DIN 17100 is also specified in the DIN standard as a structural steel. In subsequent information, it was determined that DIN 17100 had in fact been superceded by DIN 1626. In November, 1987 in order to resolve these and other questions, the P.E.I. Energy Corporation sent the Chief Boiler Inspector, Miller West, to Europe to visit a number of steel mills to determine if the DIN steel used by I.C.Moller could be deemed to be acceptable. It was determined that in fact DIN 1626 was functionally identical in material composition to API 5L and as such was acceptable under the ANSI B31 power piping Code. In essence all the steel mills had to do was to provide the mill test certificate in accordance with the Requirements of the ANSI/ASME Code.

Steel produced and used in the majority of district heating piping suppliers in Europe appears to be acceptable under the ANSI B31 code because it is functionally identical to API 5L. The Phase 2 pipe order therefore used Standard I.C.Moller fittings and pipe. The only area of concern was that special attention was paid to sourcing steel from steel mills that routinely produce pipe for the North American market and are knowledgeable of the Specification and Documentation required. The average installed cost of the U.P.E.I. system was C$355/meter for a total pipe trench length of 6.17 kilometers.

4.2 Shut-off Valves

One problem of the Phase 1 University design was that had not been encountered in earlier projects was the requirement for buried insulated shut-off valves. A great deal of time was taken to determine whether standard North American valves would be available that could be sent to I.C.Moller for pre-insulation. In the final event it proved possible for the Standard NAF valves used by I.C.Moller to use API 5L steel especially sourced by NAF that was acceptable to the Regulatory Authorities. In Phase 1 the shut-off ball valves in the buildings were supplied by NEWCO. In Phase 2 it proved possible to order a complete valve shipment from NAF that was significantly less expensive than installed costs of valves from North American suppliers. The main reason for this cost saving was that for outside valve installations expensive drain chamber construction was not required.

4.3 Control Valves

No particular change was made between the earlier Pilot Project and the University project in that Tour & Anderson control packages were again used. However, bronze-bodied Tour & Anderson valves had been registered during the interim and given a Canadian Registration Number and were used throughout the project.

4.4 Heat Exchangers

Again, following the success of the performance of the ELGE heat exchangers, ELGE heat exchangers were specified for all buildings in Phase 1 and Phase 2 of the University project. Again, copper core assemblies were sent over from Sweden together with pre-cut and rolled steel components which had heat numbers and mill test certificates as required by the Regulatory Authorities. In addition a number of smaller brazed plate-type heat exchangers were used which because of their small dimensions and small volumes were registered as fittings.

4.5 Heat Meters

Following the poor performance of the heat meters installed in the earlier project, a re-examination was made of the two heat meter suppliers, SVM and Clorius, that were preferred candidates in the previous meter selection process. It proved possible working with ISS Clorius to investigate the materials used in the construction of their meters. As a result of this exercise it was determined that the Code Requirements could be satisfied and the ISS meters were issued a Canadian Registration Number. The electronics of the meter were not a Code concern since all district heat controls including heat meters were specified to be low voltage. It therefore proved possible to use Clorius heat meters for all the installations of Phase 1 and Phase 2 of the district heating system.

CONCLUSIONS:

In many locations in North America, medium temperature district heating systems have to meet the requirements of ASME and ANSI Codes. It is fair to say that the combination of pressure of 16 bar (250 psig) and temperature 120°C (250°F) is an unusual one for North America and consequently, particularly with material selection, the Codes are not very compatible. In some areas, such as small size heat meters and heat exchangers, it is very difficult, if not impossible, to find North American fabricated components that offer the performance/cost ratios of the European products that have been developed and are selling into a large and competitive market. As the experience in Charlottetown shows that with persistance and ample amounts of goodwill and co-operation and understanding, ways can be found that will enable installations of standard European district heating equipment to be carried out that meet the ANSI/ASME Code requirements. In this way it has proved possible to install district heating systems using high quality materials at an acceptable installation cost.

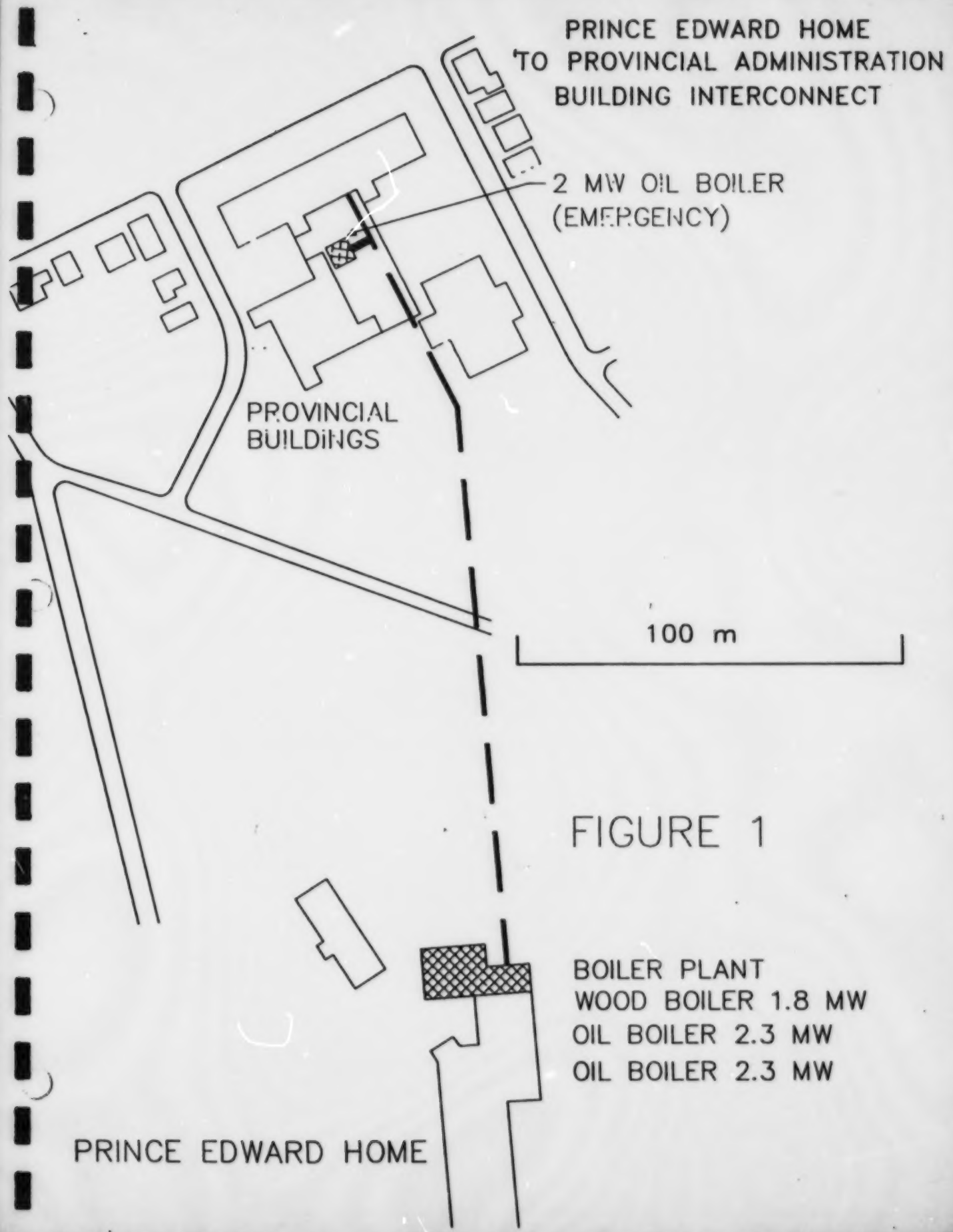
PRINCE EDWARD HOME
TO PROVINCIAL ADMINISTRATION
BUILDING INTERCONNECT
2 MW OIL BOILER
(EMERGENCY)
PROVINCIAL
BUILDINGS
100 m
BOILER PLANT
WOOD BOILER 1.8 MW
OIL BOILER 2.3 MW
OIL BOILER 2.3 MW
PRINCE EDWARD HOME

FIGURE 1

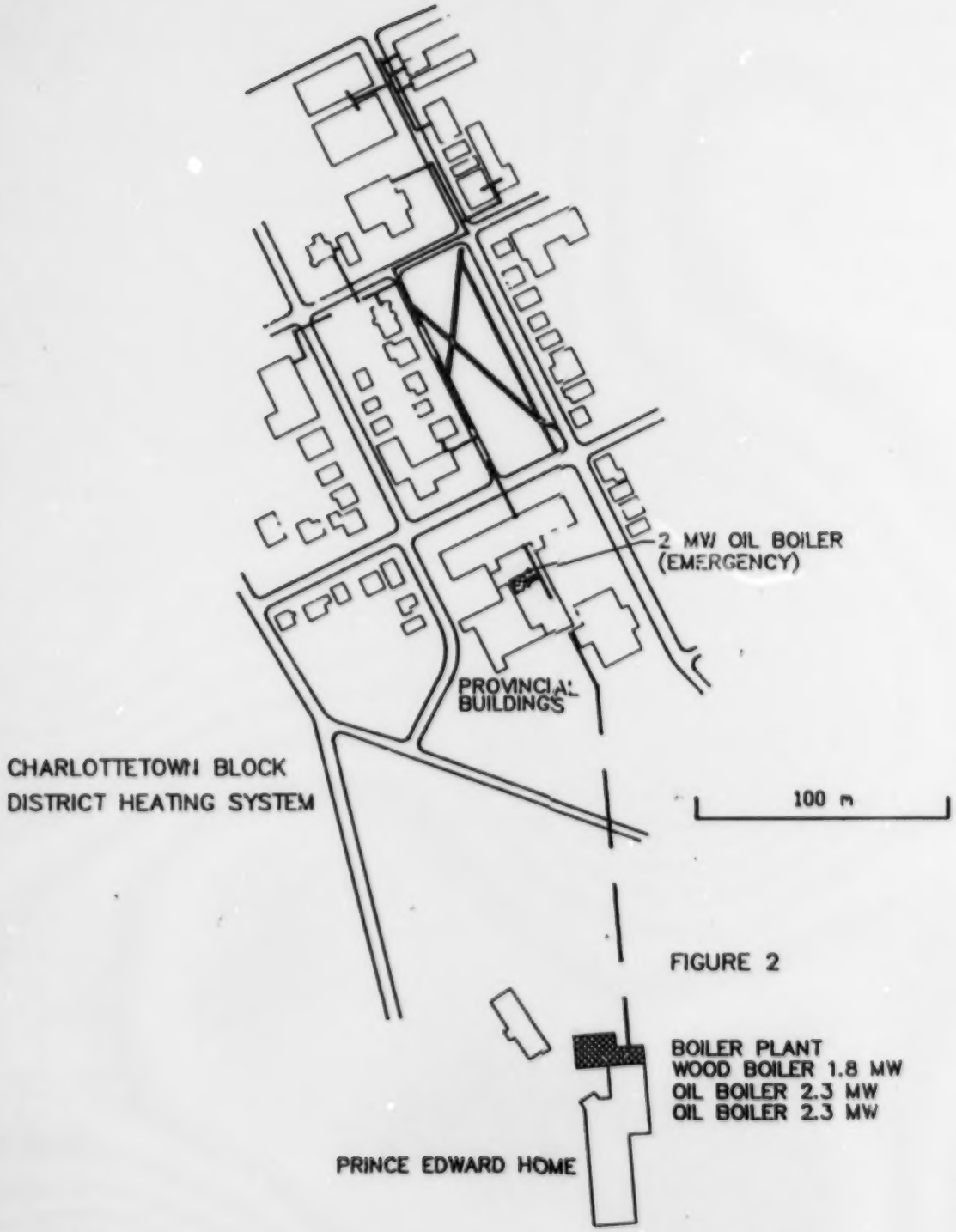
2 MW OIL BOILER
(EMERGENCY)
PROVINCIAL
BUILDINGS
CHARLOTTETOWN BLOCK
DISTRICT HEATING SYSTEM
100 m
BOILER PLANT
WOOD BOILER 1.8 MW
OIL BOILER 2.3 MW
OIL BOILER 2.3 MW
PRINCE EDWARD HOME

FIGURE 2

U.P.E.I. BLOCK CENTRAL HEATING

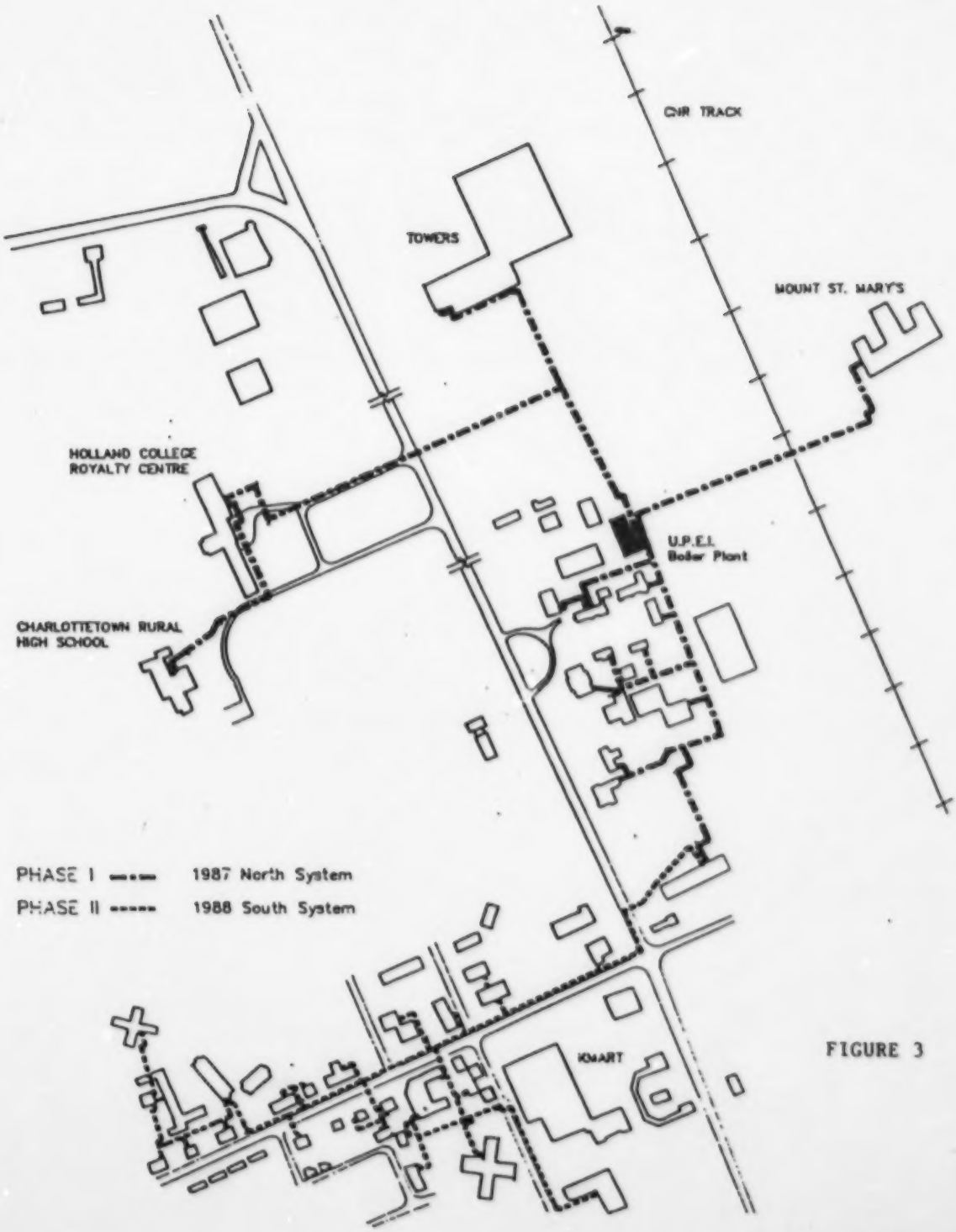

FIGURE 3